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FINAL REPORT ON CONTRACT N00014-67-A-0317-0010.(U)

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10 Gunter Weller

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PERSONNEL

The following personnel have been employed by the Contract during part or all of the period covered by this report:

Dr. Gunter Weller	Principal Investigator
Dr. Bjorn Holmgren	Co-Principal Investigator
Dr. K.O.L.F. Jayaweera	Co-Principal Investigator
Dr. Takeshi Ohtake	Co-Principal Investigator
Dr. Glenn Shaw	Co-Principal Investigator
Ms. Linda Spears	Graduate Student
Mr. Peter Weickmann	Student

INTRODUCTION

This report describes activities under Contract N00014-67-A-0317-0010 during the period 1 January 1974 to 30 September 1976, at the Geophysical Institute, University of Alaska.

During the report period,

During this year, our research efforts have concentrated on three general areas: (1)

~~(I)~~ Collection of climatological radiation data in the Arctic Basin and at coastal stations along the Beaufort Sea coast; (2)

~~(II)~~ Measurement and analysis of atmospheric turbidity and transmission of radiation, including study of ice crystals and acoustic soundings of the boundary layer, and (3)

~~(III)~~ Study of the radiative properties and microphysics of Arctic stratus clouds, and their large-scale features, using satellites.

The results of these studies continue to be published, and abstracts of publications which appeared during the contract period are included in this report.

RADIATION CLIMATOLOGY (G. Weller, B. Holmgren)

Daily means of the solar global radiation and the albedo recorded for the months May to October at three stations, T-3, Barrow and Prudhoe Bay, were compiled and published for the years 1971-1973. A summary of some of our research appears as a paper in Climate of the Arctic, published in 1975.

Publications:

1. Weller, G. and B. Holmgren, 1974: Summer global radiation and albedo - data for three stations in the Arctic Basin (Ice Island T-3, Barrow, Prudhoe Bay, 1971-1973). Geophysical Institute Report UAG R-229, 31 pp, Dec., 1974.

2. Weller, G., S. A. Bowling, B. Holmgren, K.O.L.F. Jayaweera, T. Ohtake, and G. Shaw, 1975: The radiation matrix in the Arctic. Proceedings of Climate of the Arctic Conference, Fairbanks, Alaska, University of Alaska, 238-244, April, 1975.

ABSTRACT

Radiative processes in the earth/atmosphere system can be represented schematically in matrix form. Some of the matrix elements in the arctic regions, in particular the radiation-aerosol interaction are described, presenting experimental data from the Arctic Basin. Vertical profiles of the optical extinction coefficient measured by airborne photometer near Barrow, Alaska, show a peak in the extinction coefficient in the lower troposphere (300 m) in spring; this is attributed to ice crystal aerosols. A secondary peak at about 2 km height is considered to be a semi-permanent haze layer, possibly of man-made origin, which is advected into the Arctic Basin. Seasonal variations of both the Ångström and optical extinction coefficients, which were measured, indicate turbidities which are lower in summer than in spring. Several case studies are presented. Data on the composition of arctic stratus clouds and ice nuclei concentrations, which are required for models of radiative transfer through these persistent summer cloud decks are also given.

AIDJEX RADIATION MEASUREMENTS (B. Holmgren, G. Weller)

Radiation measurements made during the AIDJEX Lead Experiment in March, 1974 were published.

Publications:

3. Holmgren, B. and G. Weller, 1974: Local radiation fluxes over open and freezing leads in the polar ice pack. AIDJEX Bulletin, No. 27, 149-166.

ABSTRACT

Radiation fluxes were measured over open and freezing leads in the polar pack ice off Point Barrow, Alaska, during the AIDJEX lead experiment in March 1974. When the leads freeze, the albedo increases rapidly because of the internal reflections caused by air bubbles, brine pockets, and interfaces between ice platelets. Rime flowers on the surface also increase the albedo and lower the radiative surface

temperature (-15^{o}C) compared with the undisturbed new ice on the lead (-12.6^{o}C) and the adjacent pack ice (-26.4^{o}C). During the freezing process, surface temperatures of the lead drop slowly, however, so that no sharp changes of the long-wave radiation balance occur. Ice deformation and rafting, on the other hand, change the thickness of the new ice and may affect the long-wave radiation considerably. Typically, net outgoing long-wave fluxes for clear skies and moderate winds are of the order of 100-150 millical cm^{-2} min^{-1}, compared with 50 millical cm^{-2} min^{-1} over the adjacent pack ice. Ice crystals and water vapor produced by the leads cause a flux divergence of the long-wave radiation but do not greatly affect the short-wave radiation balance. Computed radiation balances are -146 cal cm^{-2} over the open water surface of the lead, and -160 cal cm^{-2} for the frozen lead a day later.

In May, 1975 radiation sensors were installed at all four manned AIDJEX stations. The equipment consisted of two Eppley precision pyranometers, one facing up, the other down, to measure incoming and reflected short-wave radiation, respectively, and CSIRO net radiometer. All sensors were connected through amplifiers into the Navsat data acquisition system, where signals were recorded on magnetic tape. Tapes exist for all stations for the duration of the experiment, but spot checks and analyses have shown noise problems for long periods. The tapes remain unanalyzed in the AIDJEX data bank.

ATMOSPHERIC TURBIDITY (G. Shaw, B. Holmgren, G. Weller)

Photometric measurements with a device designed by Shaw and constructed at the Geophysical Institute were made, mostly at Barrow. Several papers were published during the contracting period. The following abstracts show the nature and results of this research.

Publications:

4. Holmgren, B., G. E. Shaw and G. Weller, 1974: Turbidity in the Arctic atmosphere. AIDJEX Bulletin, No. 27, 135-148, Nov. 1974.

ABSTRACT

Pyrheliometric and photometric measurements during the AIDJEX pilot studies in April, 1972 and March, 1974 show unexpectedly high values of the turbidity as expressed by the Ångström turbidity coefficient β. Vertical profiles of the optical extinction coefficient measured by airborne photometers indicate a peak in the extinction coefficient in the lower troposphere (300 m) in spring; this is attributed to ice crystal aerosols, and the aerosol production is explained in relation to open leads and moisture entrainment into the boundary layer. A secondary peak at about 2 km height is considered to be a semi-permanent haze layer, possibly of man-made origin, which is advected into the Arctic Basin.

5. Shaw, G. E., 1975: The vertical distribution of tropospheric aerosols at Barrow, Alaska. Tellus, 27(1), 39-50, Jan., 1975.

ABSTRACT

The vertical distribution of tropospheric aerosols near Barrow, Alaska (latitude 71°21'N, longitude 156°30'W) was determined by measuring the optical atmospheric transmission in the mid-visible at different altitudes with an airborne photometer. Measurements of the vertical aerosol distribution for periods in April and July 1972, are discussed. The aerosol concentration for both periods decreased exponentially with increasing height with a scale height equal to 1.4±0.3 km. A seasonal variation in turbidity (and the corresponding columnar aerosol loading) was found. In general, the spring turbidity values were larger than the mid-summer values, thereby suggesting an aerosol mechanism which operates at low temperatures. It is hypothesized that the aerosols may be ice crystals seeded by open leads and mixed into the troposphere. A minimum value of aerosol optical depth (T_D = 0.05±0.01) occurred after the passage of a cold front. Possible effects of ice crystal aerosols on the heat budget of the arctic basin are discussed.

This work continued under a separate ONR contract in 1976 and results will be reported on elsewhere.

ICE CRYSTALS IN THE ATMOSPHERE (T. Ohtake)

In relation to radiative heat balance, atmospheric ice crystals have been systematically observed in the Arctic coastal areas. These crystals are effective in reducing solar energy at the ground and

infrared radiative heat transferred from the ground to the sky and vice versa. An acoustic sensor for ice crystal counting with a pulse height analyzer and a digital printer was set up at NARL, Barrow to record cumulative numbers (or concentration) of the ice crystals in the air every 30 minutes. Also an ice crystal replicator recorded the shape, size and concentration of ice crystals continuously and confirmed the concentration data obtained by the ice crystal counter.

A piece of dry ice was lifted by a small balloon every day to detect saturated air which could be seen as a vertical condensation trail. An airborne ice crystal replicator to record vertical distribution of the ice crystals was successfully lifted by a kite and a balloon to the 2000 ft. level. Vertical distribution of temperature, pressure and humidity was also observed in the lowest 1000 ft. levels at NARL by use of a new balloon meteorological package. The dry ice liftings, conducted with the cooperation of National Weather Service personnel at Barrow confirmed that the humidity data provided by rawinsondes were fairly accurate on the days under low temperature conditions.

An acoustic sounder and other methods (replicators etc.) were used to determine the precipitation of ice crystals from a clear sky at Barrow. Significant diurnal fluctuations were noticed and explained in terms of a diurnally expanding mixing layer, as seen by the acoustic sounder.

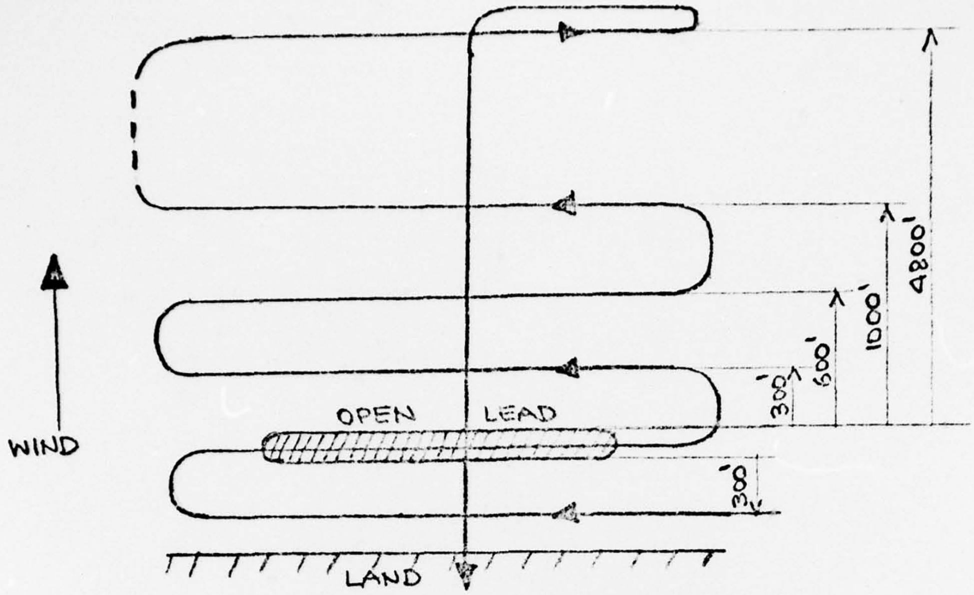
Publications:

6. Ohtake, T. and B. Holmgren: Ice crystals from a cloudless sky. Proceedings Conf. on Cloud Physics, AMS, Tuscon, Arizona, 317-320, Oct. 74.

DIFFUSION OF WATER VAPOR FROM OPEN LEADS (T. Ohtake)

The radiative heat balance over the arctic pack ice is largely affected by supercooled water clouds and ice crystal clouds as well as the water vapor content of the atmosphere. Water vapor sources of the arctic clouds, including water clouds and atmospheric ice crystals, seem to be the open leads of the arctic pack ice as an adjacent major source and the oceans at lower latitudes as long distance sources. A precise knowledge of humidity profiles in the lower atmosphere is essential in the fields of air-sea interaction, radiation, cloud physics and meteorology in general, but measurements of humidity are very difficult, especially at low temperatures. Recently a new Vaissala hygrometer became available to make humidity measurements possible from aircraft. We used this instrument to measure water vapor and its diffusion in the lower atmosphere away from an open lead acting as a simple water vapor line source.

The new hygrometer sensor is based upon the capacitance change of a polymer thin film capacitor. The thin polymer layer reacts very fast and, therefore, the response time is short enough for airplane observations. The sensor responds to humidity between 0 and 100%, is essentially linear, has small hysteresis, and negligible temperature dependence. The hygrometer reading was continuously recorded together with temperature readings by use of a thermistor, thermometers and a recorder. A Twin Otter airplane equipped with these instruments made observations above the Arctic Ocean near Barrow, Alaska. The flight pattern stepped in 200 ft. vertical intervals from 300 ft. windward, to above the open lead, and the 300 ft, 600 ft, 1000 ft, and 4800 ft downwind, parallel to the direction of the open lead, as shown.



The desirable wind direction would be perpendicular to the open lead. The original schedule for the observation was the middle of April, 1976. Unfortunately, the late arrival of the hygrometer from the factory obliged postponement to the middle of June, 1976, when some surfaces of the pack ice were already melting, so that the 6 km wide open lead which was selected was not the only vapor source, it was nevertheless a major source.

Although the data reduction is still in progress, some interesting results are as follows:

1) Relative humidities were smaller at the lower altitudes near the sufaces of both pack ice and open lead. However, since the temperature profiles were not absolutely stable, in other words, the surface air was slightly warmer than the upper air, absolute humidities or water vapor pressures calculated from the relative humidity and temperature records were consistently greater at the lower altitudes. These were consistent only in the lower boundary layer which varied between 400 and 1500 ft. from day to day.

2) The humidity profiles were about 0.85 mb/1000 ft. (or 0.28 mb/100m) in the boundary layer.

3) Temperatures over the open lead were usually slightly lower than those over the pack ice and the temperatures over land were considerably higher than anywhere else, probably due to solar radiation.

4) Traverse flights showed considerable increase of water vapor in the leeward of the open lead. Such increases of water vapor were found as far as 4 km from the windward edge of the open lead at both 500 ft and 1000 ft altitude.

Though the study is not completed yet, the present measurements of water vapor diffusion from the open lead into the lower atmosphere verified the capability of the capacitance transducer hygrometer and opened new approaches for finding water vapor turbulent diffusion coefficients in the lower atmosphere under various atmospheric stabilities. Unfortunately, because of late delivery of the hygrometer from the factory, the experiment was not conducted at the best time. If the measurements had been made in March or April, the open lead would have been an ideal line source for water vapor. Further measuremnt of this kind are highly desirable in the future.

Publications: In preparation.

ACOUSTIC SOUNDINGS OF THE ATMOSPHERE (B. Holmgren, L. Spears)

Results of acoustic soundings performed at Barrow during the AIDJEX Lead Experiment were published.

Publications:

7. Holmgren, B. and L. Spears, 1974: Sodar investigation of the effect of open leads on the boundary layer structure over the Arctic Basin. AIDJEX Bulletin, No. 27, 167-179.

ABSTRACT

During the AIDJEX Lead Experiment in February - April, 1974, a vertically pointed sodar (Sound Detecting and Ranging) was operated continuously at Barrow, Alaska, for one month. Stable conditions prevailed practically all the time. Two distinct flow types were recognized. One was characterized by a diffuse backscatter over a depth ranging from the lowest probing height of 25 m up to elevations of 400 - 500 m. This diffuse backscattering layer, which often but not always had a sharp upper boundary, apparently corresponds to the forced mixing boundary layer first investigated in detail by Sverdrup. The other turbulence regime, representing conditions of a higher overall stability, was characterized by quasi-horizontal multiple echo bands of varying thickness. The transition from a diffuse backscattering deep layer into band echoes was often gradual. A few times the acoustic record indicated transitions of the boundary structure that might have been related to open leads on the upwind side of the antenna. Two such cases are briefly discussed here.

<u>EMISSIVITY OF ARCTIC STRATUS CLOUDS</u> (K.O.L.F. Jayaweera)

We participated in the NCAR Electra flights which took place as part of the AIDJEX program. Radiation data from PRT-5 and 6 radiometers, cloud droplet spectra and the liquid water content of these clouds were measured on the flights. The flights were conducted on the 19th and 23rd of July 1975, along a path from Point Barrow to the AIDJEX site (approximately lat. 74^{o}N long. 140^{o}W). During these two day, radiance and temperature measurements were made in four cloud layers and one low level arctic fog. On the 23rd the two cloud layers were one above the other. In all clouds except those encountered on the 23rd the emissivity was less than 0.5 and the top part of the clouds showed very low emissivities. The higher cloud on July 23rd showed an overall emissivity of 0.4. This cloud showed an inversion at the top similar to that observed for other stratus clouds. The results are presented in table 1.

TABLE 1

Cloud No.	Date	Cloud Base Height (m)	Cloud Base Temp (°C)	Cloud Base IR Temp (°C)	Cloud Top Height (m)	Cloud Top Temp (°C)	Cloud Top IR Temp (°C)	Emissivity
1.	July 19, 1975	4085	-7.2	0.8	4320	-13.3	-3.6	0.41
2.	July 19, 1975	3100	-8.1	0.6	4000	-11.2	-4.0	0.47
3.	July 19, 1975	400	4.0	2.3	600	3.0	2.3	0
4.	July 23, 1975	540	-5.0	-0.5	725	-5.5	-2.9	0.51
5.	July 23, 1975	2338	-7.1	-2.2	4562	-21.2	-13.4	0.94

The data can be used to interprete satellite imagery in the thermal infrared from the very high resolution radiometer aboard the NOAA 3 and 4 satellites. A start was made to classify the clouds into stratus, stratocumulus and cirrus and their boundaries were contoured. The infrared imagery will be used to obtain the radiative temperatures of the Arctic Basin and hence the total outgoing radiative fluxes will be calculated.

Publications: In preparation

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